CLAIMS

1. A system for estimating the position, speed and orientation of a vehicle (10), comprising:

- means for determining the components of two noncollinear constant unit vectors $\vec{g}_b, \vec{e}_b$ according to vehicle body axes;

- means for determining the components of said noncollinear constant unit vectors $\vec{g}_t, \vec{e}_t$ according to the Earth's axes; and

- means for determining the three components of the angular velocity $\vec{\omega}_b$ of the vehicle in body axes.

characterized in that the system comprises

- means for correcting said angular velocity $\vec{\omega}_b$ with a correction u_ω and obtaining a corrected angular velocity $\hat{\omega}_b = \vec{\omega}_b + u_\omega$;

- a module for integrating the kinematic equations (13) of the vehicle receiving the corrected angular velocity $\vec{\omega}_b$ as input and providing the transformation matrix $\hat{B}$ for transforming Earth's axes into vehicle body axes and the orientation of the vehicle in the form of Euler angles $\hat{\Phi}$;

- a synthesis module (15) of the components in body axes of the two noncollinear constant unit vectors to provide an estimation of said noncollinear vectors in body axes $\hat{g}_b, \hat{e}_b$, where said estimation is calculated as follows:

$$\vec{g}_b = B\vec{g}_t$$
$$\vec{e}_b = B\vec{e}_t$$

- a control module (14) implementing a control law to calculate said correction u_ω, where said control law is:

$$u_\omega = \sigma(\vec{g}_b \times \hat{g}_b + \vec{e}_b \times \hat{e}_b) \qquad [1]$$

where σ is a positive scalar,

such that by applying this correction u_ω to the measured angular velocity $\vec{\omega}_b$ and using the resulting angular velocity $\hat{\omega}_b = \vec{\omega}_b + u_\omega$ as input to the module for integrating the kinematic equations, the latter are stable in the ISS sense and the error in the estimation of the direction cosine matrix $\hat{B}$ and of the Euler angles $\hat{\Phi}$ is bounded.

2. A system according to claim 1, characterized in that said noncollinear unit vectors $\vec{g}, \vec{e}$ are local gravity $\vec{g}$ and projection of the magnetic field on the plane

perpendicular to gravity $\vec{e}$.

3. A system according to claim 2, characterized in that the means for determining the components of the two noncollinear constant unit vectors $\widehat{g}_b, \widehat{e}_b$ according to vehicle body axes include:

- an Inertial Measurement Unit (IMU) (21) including a group of at least three gyroscopes (211) and at least three accelerometers (212) located along the vehicle body axes;
- a magnetometer (22) able to measure the Earth's magnetic field according to the vehicle body axes;
- static pressure (231) and differential pressure (232) sensors;
- two vanes (24) to measure the angles of attack (241) and side slip (242);
- an angular velocity acquisition and processing module (11) configured to acquire the angular velocity $\widehat{\omega}_b(t)$ and delay it to obtain $\widehat{\omega}_b(t-\tau)$;
- a data acquisition and processing module (17) configured to acquire the specific force $\widehat{a}_b(t)$ measured by the accelerometers (212), the static pressure $\widehat{p}_s(t)$ measured in sensor (231), the differential pressure $\widehat{p}_d(t)$ measured in sensor (232), the angle of attack $\widehat{\alpha}(t)$ measured in sensor (241), the angle of sideslip $\widehat{\beta}(t)$ measured in sensor (242) and the value of the Earth's magnetic field $\widehat{m}_b(t)$ measured in the magnetometer (22), delay them and process them to calculate the true airspeed $\widehat{v}(t-\tau)$, the airspeed in body axes $\widehat{v}_b(t-\tau)$ as follows:

$$\widehat{v}_b = \begin{bmatrix} \widehat{v}\cos\widehat{\alpha}\cos\widehat{\beta} \\ \widehat{v}\sin\widehat{\beta} \\ \widehat{v}\sin\widehat{\alpha}\cos\widehat{\beta} \end{bmatrix},$$

the numerical derivative of the airspeed in body axes $\dot{\widehat{v}}_b(t-\tau)$,

the local gravity in body axes $\widehat{g}_b$ as follows:

$$\widehat{g}_b(t-\tau) = \dot{\widehat{v}}_b(t-\tau) + \widehat{\omega}_b(t-\tau) \times \widehat{v}_b(t-\tau) - \widehat{a}_b(t-\tau)$$

and the projection of the Earth's magnetic field on the horizontal plane perpendicular to local gravity $\vec{e}(t-\tau)$ as follows:

$$\widehat{e}_b(t-\tau) = \widehat{m}_b(t-\tau) - \widehat{m}_b(t-\tau) \cdot \frac{\widehat{g}_b(t-\tau)}{|\widehat{g}_b(t-\tau)|}.$$

4. A system according to claim 3, characterized in that the means for knowing the

components of the two noncollinear constant unit vectors $\vec{g}_t, \vec{e}_t$ according to Earth's axes include:

- a GPS (Global Positioning System) receiver (25);

and in that the data provided by the GPS are acquired, processed and used in said data acquisition and processing module (17) to calculate the components of the two noncollinear constant unit vectors $\vec{g}_t, \vec{e}_t$ according to the Earth's axes.

5. A system according to claim 3, characterized in that the system includes a Savitzky-Golay filter (179) where $\dot{\hat{v}}_b$, numerical derivative of $\hat{v}_b$, is calculated.

6. A system according to claim 1 including:

- means of acquiring data from a group of sensors (25, 231) located in the vehicle, providing position and speed according to Earth's axes $\hat{P}_t, \hat{V}_t$;

- means of acquiring data from another group of sensors (212) located in the vehicle, providing specific force $\hat{a}_b$ in body axes;

- a navigation module where the navigation equations of the vehicle are integrated from the specific force $\hat{a}_b$ and the direction cosine matrix $\hat{B}$ to obtain calculated position and speed in local axes and corrected in a Kalman filter to obtain estimated position and speed in local axes.

7. A method for estimating the position, speed and orientation of a vehicle (10) comprising:

- calculating the components of two noncollinear constant unit vectors $\hat{g}_b, \hat{e}_b$ according to vehicle body axes from measurements of sensors located in the vehicle according to the body axes of the latter;

- calculating the components of said noncollinear constant unit vectors $\vec{g}_t, \vec{e}_t$, according to the Earth's axes from measurements of sensors located in the vehicle which provide position in local axes;

- measuring the three components of angular velocity $\hat{\omega}_b$ of the vehicle in body axes;

- correcting the angular velocity $\hat{\omega}_b$ with a correction u_ω and obtaining a corrected angular velocity $\hat{\omega}_b = \hat{\omega}_b + u_\omega$;

- integrating the kinematic equations of the vehicle, according to the corrected angular velocity $\hat{\omega}_b$ and providing the transformation matrix $\hat{B}$ for transforming the Earth's axes into vehicle body axes and the orientation of the vehicle in the form of

Euler angles $\hat{\Phi}$;

- calculating an estimation of the components in body axes of the two noncollinear constant unit vectors $\hat{g}_b, \hat{e}_b$, where said estimation is calculated as follows:

$$\hat{g}_b = \hat{B}\vec{g}_t$$
$$\hat{e}_b = \hat{B}\vec{e}_t$$

- obtaining the correction u_ω by means of the control law:

$$u_\omega = \sigma(\widehat{g}_b \times \hat{g}_b + \widehat{e}_b \times \hat{e}_b) \qquad [1]$$

where σ is a positive scalar,

such that upon applying this correction u_ω to the measured angular velocity $\widehat{\omega}_b$ and using the resulting angular velocity $\hat{\omega}_b = \widehat{\omega}_b + u_\omega$ as input to the module for integrating the kinematic equations, the latter are stable in the ISS sense and the error in the estimation of the direction cosine matrix $\hat{B}$ and of the Euler angles $\hat{\Phi}$ is bounded.

8. A method according to claim 7, characterized in that said noncollinear unit vectors $\vec{g}, \vec{e}$ are local gravity $\vec{g}$ and projection of the magnetic field on the plane perpendicular to gravity $\vec{e}$.

9. A method according to claim 8, characterized in that it comprises:

- measuring specific force $\widehat{a}_b(t)$, static pressure $\widehat{p}_s(t)$, differential pressure $\widehat{p}_d(t)$, angle of attack $\widehat{\alpha}(t)$, angle of sideslip $\widehat{\beta}(t)$ and the value of the Earth's magnetic field $\widehat{m}_b(t)$;

- calculating the true airspeed $\widehat{v}(t)$ from the differential pressure $\widehat{p}_d(t)$ and static pressure $\widehat{p}_s(t)$ measurements and from knowing the outside temperature at the initial moment T_0;

- calculating the airspeed in body axes as follows:

$$\widehat{v}_b = \begin{bmatrix} \widehat{v}\cos\widehat{\alpha}\cos\widehat{\beta} \\ \widehat{v}\sin\widehat{\beta} \\ \widehat{v}\sin\widehat{\alpha}\cos\widehat{\beta} \end{bmatrix};$$

- delaying a time τ the angular velocity $\widehat{\omega}_b(t)$, specific force $\widehat{a}_b(t)$, magnetic field $\widehat{m}_b(t)$ and airspeed in body axes $\widehat{v}_b(t)$;

- calculating the numerical derivative of the airspeed in body axes $\dot{\widehat{v}}_b(t-\tau)$;

- calculating the local gravity in body axes $\hat{g}_b$ as follows:

$$\hat{g}_b(t-\tau)=\dot{\hat{v}}_b(t-\tau)+\hat{\omega}_b(t-\tau)\times\hat{v}_b(t-\tau)-\hat{a}_b(t-\tau)\text{; y,}$$

- calculating the projection of the Earth's magnetic field on the horizontal plane perpendicular to local gravity as follows:

$$\hat{e}_b(t-\tau)=\hat{m}_b(t-\tau)-\hat{m}_b(t-\tau)\cdot\frac{\hat{g}_b(t-\tau)}{\left|\hat{g}_b(t-\tau)\right|}.$$

10. A method according to claim 9, characterized in that the position in Earth axes $\hat{P}_t$ is measured and from this measurement the components of the two noncollinear constant unit vectors $\vec{g}_t,\vec{e}_t$ are calculated according to the Earth's axes.

11. A method according to any of claims 9-10, characterized in that $\dot{\hat{v}}_b$, the numerical derivative of $\hat{v}_b$, is calculated in a Savitzky-Golay filter (179).

12. A method according to any of claims 7-11 including:

- measuring position and speed in Earth-fixed axes $\hat{P}_t,\hat{V}_t$;
- measuring specific force $\hat{a}_b$ in body axes;
- integrating the navigation equations of the vehicle according to the specific force $\hat{a}_b$ and the direction cosine matrix $\hat{B}$ to obtain the calculated position and speed in local axes and they are corrected in a Kalman filter to obtain estimated position and speed in local axes.